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"Survival of the Grouped" or Three's a Crowd? Repetition Blindness in Groups of Letters and Words

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“Survival of the Grouped” or Three’s a Crowd? Repetition Blindness in Groups of Letters and Words

By

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Abstract

Repetition blindness (RB) refers to the failure to detect both occurrences of an item when that item is presented twice (Kanwisher, 1987). What happens when more than two items are presented, specifically, what happens when items are presented in groups of three? Four experiments were conducted wherein groups of letters and words were presented sequentially and simultaneously and reaction times on a judgment of frequency response, which allows for determination of participant strategy, was collected. Results indicated that when items are presented sequentially, RB and an item enumeration strategy are observed. When items are presented simultaneously, however, it appears as though a mix of strategies is used. Specifically, those who exhibited greater accuracy at detecting the group of three items had faster reaction times, suggesting a familiarity-based strategy and those who exhibited RB for the group had slower reactions, suggesting an item enumeration strategy.

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Introduction

Paramount to comprehending human language from a neurocognitive perspective is understanding how words are accessed, processed, and stored in the brain. These concepts can be systematically explored through various manipulations of the conditions that produce a phenomenon called repetition blindness. Repetition blindness (RB) is a reliable and robust effect that operates at the interface of language, perception, and memory. It refers to the inability to detect the second occurrence of a visual stimulus, when multiple items are presented at a rapid pace (Kanwisher, 1987). The speed of presentation needed to achieve this effect is about 100-150 ms per item and can be attained either through the use of rapid serial visual presentations (RSVPs) or brief simultaneous visual presentations (BSVPs) (Kanwisher, 1991; Luo & Caramazza, 1996). In order to gain a full appreciation of what repetition blindness is and what it can tell us about the processing of language, it is important to consider the conditions that modulate this effect, along with the possible mechanism(s) that best explain all the data.

Repetition blindness is an online, perceptual process that functions at the level of encoding (Epstein & Kanwisher, 1999; Kanwisher, Kim & Wickens, 1996; Luo & Caramazza, 1996; Neill et al., 2002). Based on the lack of a repetition blindness effect when using auditory stimuli such as spoken words, RB is hypothesized to occur relatively early, before auditory and visual inputs converge (Kanwisher & Potter, 1989). This processing, while early, is still at a fairly abstract level because RB also acts on a general stimulus identity rather than a strict visual form. For example, it occurs even when letters or words differ in case (e.g., “a” and “A” or “sofa” and “SOFA”) (Bavelier & Potter, 1992; Kanwisher, 1987; Schenden et al., 1997) or in orientation (Corballis & Armstrong, 2007; Coltheart, Mondy & Coltheart, 2005). Moreover, exact stimulus identity, does not seem to be a requirement: repetition blindness has been found for a number of merely similar items, such as ones that share phonology, orthography, and conceptual/semantic identity (see Table 1). In these cases, while RB is present, it appears not to be as robust as when the items are exactly alike along all dimensions (Bavelier, 1994; Harris & Morris, 2000; Stoltz & Neely, 2008).

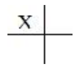
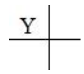
Bolstering its status as a perceptual phenomenon, RB is unaffected by manipulations designed to reduce memory loads, such as when participants are pre-cued with the target’s identity (Kanwisher, 1991); instructed to perform concurrent articulation which prevents rehearsal in short term memory (Bavelier & Potter, 1992); required only to report the repeated item rather than all items in the RSVP stream (Bond & Andrews, 2008); required only to press a key the moment a target is detected (Morris & Harris, 2004); and view only two item displays (Kanwisher et al., 1995). Supporting this contention, a study using event-related potentials (ERPs) to compare instances of repetition blindness to instances in which repetition was correctly detected and to instances in which errors were made for unrepeated items, found differences as early as 220 and 400 ms after onset of the second target item (Schenden, Kanwisher & Kutas, 1997). These differences are hypothesized to represent an initial misclassification of the repetition as a novel item (220ms) followed by a lack of an effect associated with correct report (400ms) (Schenden et al., 1997).

Table 1

Stimuli Vulnerable to Repetition Blindness

Stimulus	Example	Authors and Year of Publication
Words	radio-radio	Abrams et al. (1996); Bond & Andrews (2008); Campbell et al. (2002); Coltheart & Langdon (2003); Hochhaus & Marohn (1991); Kanwisher & Potter (1989); Kanwisher & Potter (1990)
Words in different cases	sofa-SOFA	Kanwisher (1987); Schendan et al. (1997)
Orthographic neighbors	YARN-barn	Morris & Harris (2002); Harris & Morris (1998, 2000, 2004)
Homophones	eight-ate	Bavelier & Potter (1992)
Letter clusters	prime-blame	Harris (2001); Harris & Morris (2000, 2001); Morris & Harris (1999)
Letters	A-A	Anderson & Neill (2002); Kanwisher (1991); Kanwisher et al. (1995); Kanwisher et al. (1996); Luo & Caramazza (1996); Neill et al. (2002)
Letters in different cases	A-a	Bavelier & Potter (1992)
Letters in different orientations	F- Ⅎ	Corballis & Armstrong (2007)
Pronounceable nonwords	narp-narp	Morris & Harris (1999) Morris & Still (2008); Harris & Morris (2004)
Chinese characters	日 - 日	Wong & Chen (2009)
Arabic and verbal digits	two-2	Bavelier & Potter (1992)
Picture and words	sun - 	Bavelier, D. (1994)
Picture and word homophones	son- 	Bavelier, D. (1994)

Table 1 – Continued

Stimulus	Example	Authors and Year of Publication
Spatial locations	 - 	Epstein & Kanwisher (1999)
Novel objects	 - 	Coltheart et al. (2005)
Colors	(red) - (red)	Goldfarb & Treisman (2011); Kanwisher (1991); Kanwisher et al. (1995)

Repetition blindness is also indifferent to both grammar and coherence of sentences. This is most clearly seen in RSVP sequences that, when read together, make a complete, coherent sentence only when the repeated word is detected, yet participants still consistently fail to report it (Bavelier, 1994; Bond & Andrews, 2008; Harris & Morris, 1998; Kanwisher, 1987; Kanwisher & Potter, 1990; Kanwisher & Potter, 1998; MacKay & Miller, 1994; Morris & Harris, 2002; Morris & Harris, 2004). One exception to this was reported by Abrams, Dyer and MacKay (1996), who found that when sentences presented in an RSVP paradigm were either presented as syntactically correct phrases (e.g., "They wanted/to play sports/but sports/were not allowed") or syntactically incorrect phrases (e.g., "They wanted to/play sports but/sports were not/allowed"), repetition blindness was only found in the syntactically incorrect phrase condition. They hypothesize this kind of grouping is akin to that found for spoken words, arguing that RB likely exists for auditory stimuli, but is prevented by the phrase grouping that occurs with naturally spoken sentences (Abrams et al., 1996).

Perhaps more telling than the conditions under which repetition blindness is obtained are the conditions that diminish or preclude it. Presentation mode is one such variable, with experiments employing BSVP resulting in reduced, but still robust, RB compared to those employing RSVP (Kanwisher, 1991; Luo & Caramazza, 1996). This reduction is also seen when RSVP paradigms are modified to allow for spatial displacements of the stimuli, with greater spatial displacement resulting in smaller RB effects (Hochhaus & Marohn, 1991; Kanwisher & Potter, 1989; Mozer, 1989). Research by Epstein and Kanwisher (1999) demonstrated that RB existed for spatial locations irrespective of stimulus identity, as in when participants were told to report where items appeared on a four-quadrant grid, RB occurred for two different items appearing in the exact same location. They also noted that a rudimentary, automatic coding for locations seems to work against RB, such that even when asked to report stimulus identity, RB for locations tended to still interfere (Epstein & Kanwisher, 1999). This likely operates in the same fashion as a change in any other dimension of a stimulus, in that spatial displacements help to distinguish identical items, making them functionally similar instead (Epstein & Kanwisher, 1999).

Other factors also influence the magnitude of repetition blindness, including the lag or number of items that intervene between the first and second presentations of the target stimuli. The relative amount of RB in a given experiment first increases and then decreases with lag, with the smallest amounts at lags zero and four (Harris, 2001; Kanwisher, 1987; Kanwisher et al., 1996; Luo & Caramazza, 1996). This factor is likely explained at least in part by a similar pattern of findings seen when stimulus onset asynchrony (SOA), or time between items, is systematically varied (Coltheart et al., 2005; Hochhaus & Marohn, 1991; Kanwisher, 1987; Anderson & Neill, 2002). When participants are given ample time between the item and its repetition, processing demands decrease and less errors are made (Hochhaus & Marohn). Accordingly, when more time and/or more intervening items separate the repetition, the easier it becomes to perceive it. Luo & Caramazza (1996) use a refractory period framework to suggest repetitions with no intervening items are also easier to perceive because the activation produced from the two presentations are summed.

Similarly, repetition blindness is limited by both processing capacity and attention. In order for RB to occur, the stimuli must be presented for a duration that allows for proper encoding, otherwise repetition priming is produced instead (Coltheart & Langdon, 2003; Kanwisher, 1987; Morris & Still, 2008). In fact, many failed attempts at demonstrating RB in nonwords appear to be the result of a failure by the participants to encode the first presentation of the target item, resulting in a repetition advantage that then reverses when the exposure duration to the initial presentation is lengthened (Harris & Morris, 2004).

Hochhaus and Marohn (1991) claim that heightened attention reduces RB. This claim was supported by the observation that participants made fewer errors when they anticipated repetitions. In another demonstration of the attenuating effects of attention, Campbell, Fugelsang, and Hernberg (2002) found that RB could be reduced when the salience of the second target item was increased by manipulating the relative brightness of the words. However, this attentional effect was not replicated in Kanwisher's (1991) study that increased the repetition's salience by displaying it in red. While it remains unclear whether the salience of repeated items has an effect on RB, it is clear that attention definitely impacts the dimension on which RB operates.

When stimuli have multiple dimensions that can be reported (e.g., color and identity or identity and location), repetition blindness occurs only for the dimension attended by the viewer (Epstein & Kanwisher, 1999; Kanwisher, Driver & Machado, 1995). For example, when asked to report the colors of letters, participants will be “blind” to a repeated color, but not to a repeated letter as seen in Kanwisher et al.’s (1995) research. This is seen with the unit commanding attention as well, as in the case when participants are asked to report either individual letters or complete words (Kanwisher & Potter, 1990). Likewise, complete lack of attention to any dimension or unit results in a lack of RB; further proving it’s importance to RB (Kanwisher, 1991).

Multiple explanations of repetition blindness have been put forth, including ones that insist that RB is actually best explained as a memory phenomenon (Campbell et al., 2002; Whittlesea & Masson, 2005). These accounts are less popular than the perceptual accounts, given the multiple memory manipulations RB has withstood (Bavelier & Potter, 1992; Bond & Andrews, 2008; Kanwisher, 1991; Kanwisher et al., 1995; Morris & Harris, 2004). Popular perceptual accounts are both well outlined and addressed in Kanwisher’s (1987) article and include a refractory period hypothesis and a token individuation hypothesis. The refractory period hypothesis suggests that each item’s mental representation has a refractory period in which they cannot be easily reactivated (Kanwisher, 1987). Although appealing in its simplicity and its parallel to the functioning of neurons, this account implies that blindness can only occur for the second presentation of an item, but RB has been observed for the first presentation as well (Neill et al., 2002; Wong & Chen, 2009).

The explanation that best accounts for all the data is Kanwisher's (1987) own token individuation hypothesis, which insists that the "blindness" that is occurring is actually to the distinction between the two items, or put another way, the repeated items are not recognized as two discrete events. Kanwisher (1987) proposes that the type, or mental representation stored in long-term memory, can be and is repeatedly activated and that it is the episodic token, or memory of the particular instance of a type, that's vulnerable to failure. Later, Kanwisher and Potter (1989) amended this hypothesis to include the idea that types and tokens reside in different domains – likely the ventral "what" and dorsal "where" streams – and clarified that what was meant by a token being individuated is that a bond is formed between a given type and it's newly created, respective token. Further, they hypothesized that the refractory period for token individuation results in the both presentations of an item being encompassed into the first instance of that item (Kanwisher & Potter, 1989).

However, RB does not always occur for the second presentation of an item and, as already mentioned, has also been reliably observed for the first presentation (backwards repetition blindness) (Neill et al., 2002; Wong & Chen, 2009). Bavelier and Potter (1992) took on this inconsistency by positing some additional features of tokens. Specifically, that they operate by a two-step process, the first consisting of the opening of a token and the second being the stabilization of that token in memory (Bavelier & Potter, 1992). During RB, tokens for both presentations of the items can be initially opened, but then one is subsequently lost if not properly stabilized (Bavelier & Potter, 1992). Stabilization of tokens depends on the ability to register the type's codes, or information about the type (e.g., phonology, orthography, visual form, and conceptual information) in memory and can favor the second presentation should that instance be particularly salient (Bavelier & Potter, 1992). The idea that stabilization and by extension, RB itself, relies on the specific codes registered in memory rather than exact type helps to better explain not only RB for similar items, such as items that share only phonological and conceptual identities (e.g., “eight” and “8”), but also provides a hint as to why RB is reduced when the number of shared codes is reduced (Bavelier & Potter, 1992; Stolz & Neely, 2008).

Neill et al. (2002) assigned different terms and somewhat different mechanisms to the two-step process behind token individuation. According to Neill et al. (2002), creating a token first involves a process similar to the one described by Bavelier (1992) whereby tokens are initially created based on recognition that an instance of a type has occurred, this is referred to as “instantiation.” This is followed by “contextualization”, which assigns that instance to a specific context (e.g., location, sequential order) (Neill et al., 2002). Also differing from Bavelier (1992), Neill et al. (2002) explains backwards RB, or blindness for the first presentation of an item, as still a failure at step one. This is possible because, as with traditional RB, only one token was instantiated for the two occurrences, but then during step two this token became contextualized to the second presentation instead of the first presentation (Neill et al, 2002).

Finally, the token individuation hypothesis still leaves questions as to why repetition blindness exists for both novel objects (Coltheart et al., 2005) and nonwords (Morris & Harris, 1999; Morris & Still, 2008; Harris & Morris, 2004) if it truly does rely on activation of existing types already stored in long-term memory as Kanwisher (1987) suggests. Refining the hypothesis further, Epstein and Kanwisher (1999) more clearly defined “types” as either an already existing representation in long-term memory (e,g., words) or a novel representation that can quickly be created in long-term memory (e.g. nonwords). Acknowledging that stimuli have multiple features, or codes, which can be repeated, they also confirmed and echoed Bavelier's (1992) assertion that RB can occur along any attended dimension (Epstein & Kanwisher, 1999). Potter (1999) also emphasized the importance of attention, insisting that type activation is an automatic process, whereas token individuation requires conscious allocation of attention in order to create a link to the activated type.

Without a doubt, the token individuation hypothesis (Kanwisher, 1987) provides an eloquent and thoughtful explanation of RB when dealing with two presentations of an item in an RSVP or BSVP display. But what would be the result of a display containing three presentations on a given item? Mozer (1989) investigated what he deemed the homogeneity effect using estimations of item numbers in single letter or multiple letter BSVP displays. Finding that participants consistently underestimated the number of letters when the display contained only a single letter, it would at first appear that more than two presentations of an item would have a similar, traditional RB effect (Mozer, 1989).

However Goldfarb and Treisman (2011) found a much different result using simultaneous (BSVP) displays containing either one repetition with an item intervening or three identical and consecutive colored symbols. They also further reduced processing efficacy by distracting viewers with a different, "primary" task of reading numbers at the beginning and end of each display. Quite expectedly, they observed an RB effect for the repetition condition, but instead of a similar pattern of results for the three presentations condition they actually found that these trials were perceived better (Goldfarb &

Treisman, 2011). Coining this effect “the survival of the grouped,” Goldfarb and Treisman (2011) allow current hypotheses of RB to accommodate this new data by suggesting that grouping of items allows them to be seen as a single, multifaceted item akin to a single face being composed of eyes, nose, mouth, etc. While standing contrary to Mozer’s (1989) data, the idea of grouping items to protect them from RB may help explain why studies consistently find reduced RB at lag 0, or when two items are presented without intervening items (Harris, 2001; Kanwisher, 1987; Kanwisher et al., 1996; Luo & Caramazza, 1996).

But did Goldfarb and Treisman (2011) find this effect solely because they were using simple, color-matched geometric shapes (dots and slashes)? Did Mozer (1989) report a different effect because linguistic units such as letters or words are inherently more complex and perhaps follow different rules? Are words only able to be grouped in coherent phrases, like that seen by Abrams et al. (1996) or can they be grouped by identity as well? Is this effect something that would only be seen in a BSVP display, thereby distinguishing the two paradigms that are thought to give rise to similar processes (Luo & Caramazza, 1996)? The present experiments aim to elucidate whether RB for both linguistic units and RSVP displays can be reduced or reversed by Goldfarb and Treisman’s (2011) survival of the grouped effect. While grouping has been hypothesized to be “less salient” in an RSVP display, it has yet to be tested (Goldfarb & Triesman, 2011). Experiments one and two will use both RSVP and BSVP displays of single letters, which are arguably the least complex units in language. Experiments three and four will investigate this phenomenon using four letter words in both RSVP and BSVP displays, which are not only more complex, but also carry conceptual/semantic information.

Similar to a procedure used by Brown, Buchanan and Cabeza (2000), participants will be asked to report a judgment of frequency (JOF) of a target item and their reaction time will be measured. According to Brown, Buchanan and Cabeza (2000), when JOFs are made primarily based on a familiarity-based strategy, as seen in their false memory experiment, reaction times are relatively flat. On the other hand, when subjects instead tally instances of a target item, RT increases with number of items presented (Brown, Buchanan & Cabeza, 2000). This increase in RT was seen with Wong's (2009) work when participants performed a repetition blindness task, indicating that participants were likely enumerating instances of the target item. This is consistent with the token individuation hypothesis in the sense that there is no limit to how often an item's type can be activated, as the bottleneck exists within the opening and stabilizing of tokens (Kanwisher, 1987). Mozer (1989) similarly advanced the explanation that while multiple objects could be identified at once, their location information could not be registered under attention limited conditions. Accordingly, the present experiments will also seek to determine whether a familiarity-based strategy is employed in respect to JOFs in an RB paradigm, or whether Wong's (2009) results will be replicated in support of an enumeration-based strategy.

In sum, the following experiments were designed with the purpose of answering three questions. 1) Is a "survival of the grouped" effect possible using more complex, linguistic stimuli? 2) Is a "survival of the grouped" effect possible using sequential displays? 3) Do viewers use an item enumeration strategy or a familiarity-based strategy in forming their response?

Experiment 1

Method

Participants.

Twenty University of Windsor undergraduate psychology students (18 female, mean age = 19.65 years, age range = 18-22) participated in this experiment and were subsequently awarded with partial course credit. This number exceeds the 14 participants suggested by the large effect size (at least Cohen's d = .70) found with RB and a power analysis using an alpha level of .05 and G*Power software. Participants were required to have normal or corrected-to-normal vision as well as English as a first language.

Stimulus Materials and Design.

Stimulus materials included all capital letters except the visually similar I and L, and U and V. One hundred RSVP trials were composed of 20 that included four unrepeated letters, or one presentation of the target letter (example: A-B-C-D); 20 that included one repetition, or two presentations of the target letter with one intervening item between the repetition (example: A-B-A-D); 20 that included a group, or three uninterrupted presentations of the target letter (example: A-A-A-D); 20 composed of only three unrepeated letters (example: A-B-C); and 20 composed of only two unrepeated letters (example: A-B). Trials with less than four letters were intended to reduce guessing based on the knowledge that all trials should contain four items and were not included in the analyses. Analyses were performed only on the unrepeated, repeated, and grouped trials.

Order of presentation of conditions and trials were randomized. Trials were preceded and followed by stimulus masks composed of a row of four asterisks. Letters for the trials were chosen randomly, with the exception that care was taken to ensure the sequence did not spell an English word. Letters were presented centrally and sequentially in size 14, Times New Roman font. The background screen was black and the letters were turquoise.

The independent variable in this experiment was the number of target letter presentations (one, two, or three) and the dependent variables included both mean accurate RT (time taken by participant to respond when accurate) and mean percentage correct for each level of the IV (how often each participant correctly indicated the number of target items).

Apparatus and Procedure.

Participants performed this task individually in normal room illumination. The task was executed on a PC using the Windows XP operating system and DirectRT software. Responses were made on a DirectRT compatible button bar labeled for the number of target items seen (zero through four) along with a button designated to initiate each trial. Each button press was mapped to corresponding numbers in the output file.

Experimental trials were preceded by approximately 15 trials in which an individually set exposure duration for letter presentation was determined. Exposure duration was based on a full report version of the experimental task using only four letter unrepeated trials. A rate increase of 14ms was implemented until the participant's accuracy was reduced to approximately 50%, the rate at which this was achieved was then used for the experimental trials. This cutoff was found to transfer to a slightly higher accuracy for unrepeated items on the less difficult (as it did not require report of all items) experimental task. The modal exposure duration for this experiment was 58ms with a range of 58-114ms. This initial setting was sufficient for the duration of the experiment due to a lack of practice effects observed with RB (Kanwisher et al., 1996).

Following these trials, participants performed five practice trials using the judgment of frequency report method in order to familiarize them with actual task demands. Participants were instructed to initiate a trial by pressing the appropriate button and then to note the pre-cued target letter, which was displayed for 1000 ms. After the target letter, the RSVP sequence, including masks, was presented at the exposure rate set for that individual. At the conclusion of the sequence, participants were cued to respond using the button bar, with the key press to the button corresponding to the appropriate number, as soon as they had a single numerical response in mind and then to initiate the next trial when ready.

Results

Separate one-way, repeated measures analysis of variances (ANOVAs) were conducted on the accuracy (mean percent correct) and RT data at each level of the IV (number of presentations of the critical item). Analyses were performed both by participant and by item, but they revealed a similar pattern of results. Accordingly, only the by participant data will be reported.

The ANOVA for accuracy revealed a large main effect of number of presentations, $F(2,36) = 27.20$, $p < .001$, $\eta^2 = .60$. Bonferroni-corrected comparisons were made and the expected RB effect was found as two presentations (M = 42%, SD = 22%, CI = 32-53%) resulted in reduced accuracy as compared to the single presentation condition (M = 71%, SD = 18%, CI = 62-79%, $p = .001$). As compared to one presentation, decreased accuracy was also found at three presentations of the critical letter (M = 40%, SD = 28%, CI = 27-52%, *p* = .002). Perusal of the data indicated that this, too, was a result of underestimation of items, indicating a RB effect. Results are presented graphically in Figure 1.1.

The ANOVA for RT was conducted on mean RT for correct responses. Individual RT values were removed if they exceeded 2.5 standard deviations of the mean score. Using this criterion, 25 individual cases were removed, or a total of 4% of data. The ANOVA revealed a large main effect of number of item presentations $F(2, 36) = 6.60$, $p = .004$, $\eta^2 = .27$. Bonferroni-corrected comparisons were performed and suggested a possible item enumeration strategy as three presentations (M = 1311ms, SD = 327ms, CI = 1154-1469ms) of the critical item elicited a longer reaction time than both one (M = 1066ms, SD = 300ms, CI = 927-1216, *p* = .028) and two (M = 1148ms, SD = 301ms, CI = 1004-1294ms, *p* = .008) presentations. No differences were observed, however, between one and two item presentations. Descriptive statistics are presented in Figure 1.2.

Figure 1.1

Mean Accuracy by Condition

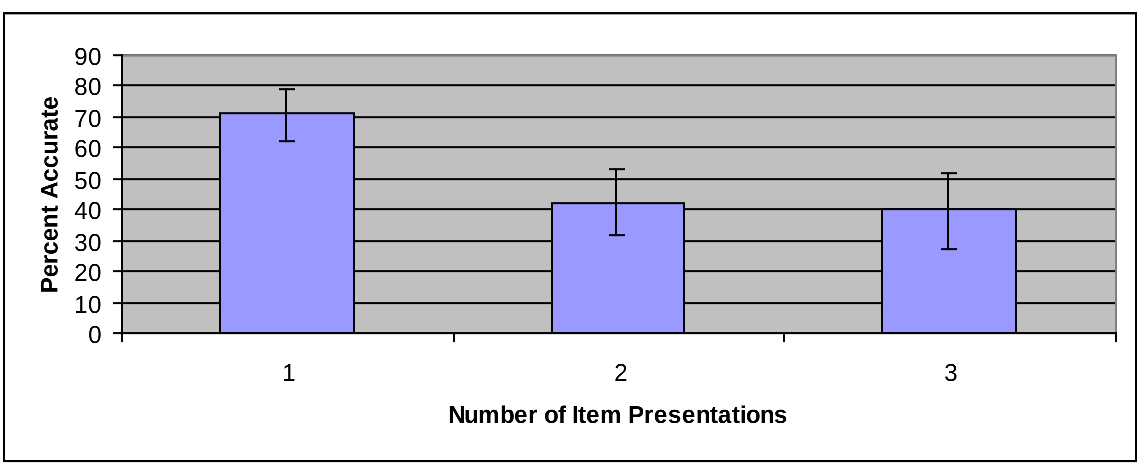
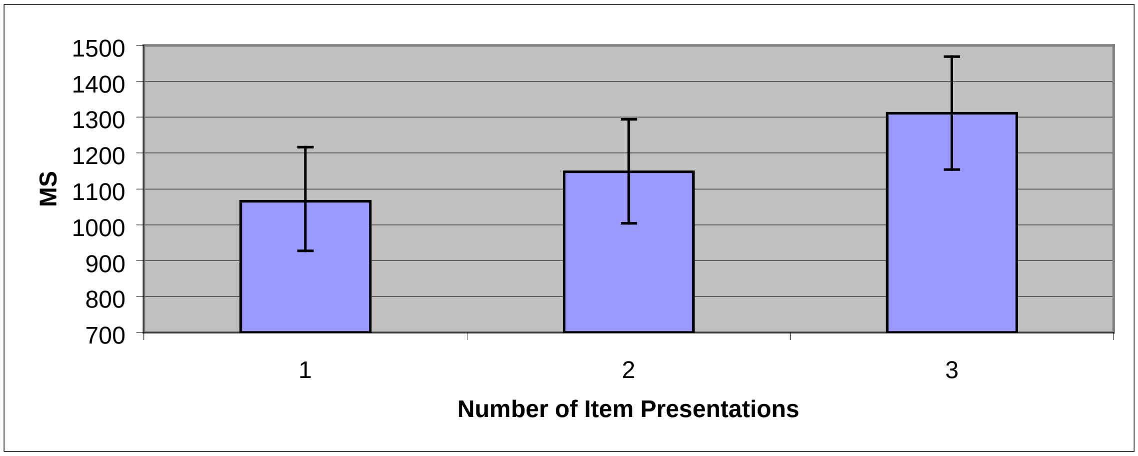


Figure 1.2

Mean RT by Condition



Discussion

The results of Experiment 1 suggest that when letters are presented sequentially using an RSVP display, an RB effect is observed when a single repetition is present, and when three identical letters are presented consecutively. It also appears as though participants approach this task by using an item enumeration strategy whereby each instance of the target letter is counted. The evidence supporting use of this strategy is not as strong as expected, however, as a difference was found only between one and three presentations of a letter with two presentations falling in the middle.

Experiment 2

Method

Participants.

Thirty-three University of Windsor undergraduate psychology students (30 female, mean age = 20.18 years, age range = 18-27) participated in this experiment and were awarded with partial course credit. This number exceeds the 14 participants suggested by the large effect size (at least Cohen's d = .70) found with RB and a power analysis using an alpha level of .05 and G*Power software. Participants were required to have normal or corrected-to-normal vision as well as English as a first language.

Stimulus Materials and Design.

Stimulus materials and design were the same as Experiment 1 with the exception that letters were presented using a BSVP format. The display as a whole was centrally located on the computer monitor with items presented simultaneously in the four quadrants of a square that was contained within 4X4 degrees of visual angle. Each letter was presented within two degrees of visual angle from the center of the square. This layout was chosen as it was thought that a traditional single line presentation might bias viewers towards a left to right reading strategy.

Apparatus and Procedure.

The apparatus and procedure were similar to those used in Experiment 1, with the exception that in this case a BSVP display was used with a modal exposure duration of 72ms with a range of 58-156ms.

Results

Separate one-way, repeated measures ANOVAs were conducted on the accuracy and RT data at each level of the IV. Analyses were performed both by participant and by item, but revealed a similar pattern of results. Accordingly, only the by participant data will be reported.

The ANOVA for accuracy found a large main effect of number of presentations, $F(2, 64) = 28.40$, $p < .001$, $\eta^2 = 0.47$. Bonferroni-corrected comparisons were made and the expected RB effect was found at two presentations (M = 71%, SD = 22%, CI = 64-80%) when compared to the one presentation condition (M = 86%, SD = 10%, CI = 82-

90%, $p < .001$). Decreased accuracy was also found at three presentations of the critical letter (M = 54%, SD = 31%, CI = 43-65%, $p < .001$) with perusal of the data indicating that this, too, was a result of underestimation of items, indicating an RB effect. More errors were also made in the three presentation condition as compared to the two presentation condition ($p = .002$). Descriptive statistics are presented in Figure 2.1.

The ANOVA for RT was conducted on mean reaction time for correct responses. Individual RT values were removed if they exceeded 2.5 standard deviations of the mean score. Using this criterion, 47 individual trials were removed, a total of 2% of data. While the ANOVA revealed a main effect of number of presentations $F(1.42, 43.88) = 3.64$, $p = .049$, $\eta^2 = .11$), [1] Bonferroni-corrected comparisons found no differences among pairs of conditions. This may be due to statistical power being reduced as a result of participants adopting different strategies for this task, which would increase the variability of results. This prospect is bolstered by the fact that despite the reduction in accuracy with more presentations, there appeared to be a group of individuals that could be classified as “high performers” in the grouped condition (three presentations).

To test this hypothesis an independent samples t-test was performed comparing the mean accurate RTs of the more accurate half of the sample (M = 80%, n = 16) to the less accurate half of the sample (M = 30%, n = 17). Accuracy was based on performance in the grouped condition. It was hypothesized that the “low performers” were using an item enumeration strategy and would therefore have increased RTs while the “high performers” were using a familiarity-based strategy and would therefore have comparatively decreased RTs. The two groups did differ $t(30) = 2.40$, $p = .023$, $\eta^2 = .40$

in the hypothesized direction with high performers producing faster [1]Greenhouse-Geisser correction applied for violation of assumption of homogeneity of variances.

reaction times (M = 1003ms, SD = 150ms, CI = 923-1082ms) than the low performers (M = 1230ms, SD = 348ms, CI = 1045-1416ms). See Figure 2.2 for data displayed graphically.

Figure 2.1

Mean Accuracy by Condition

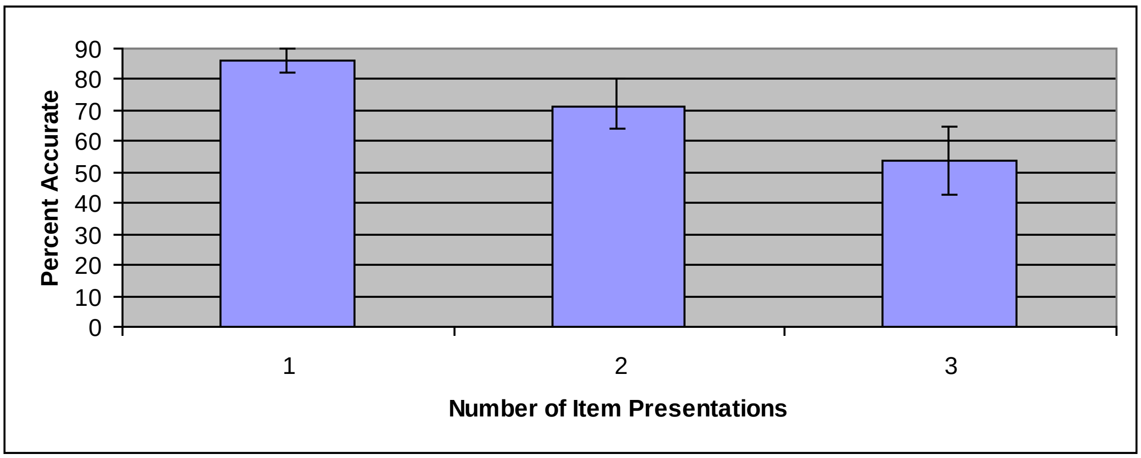
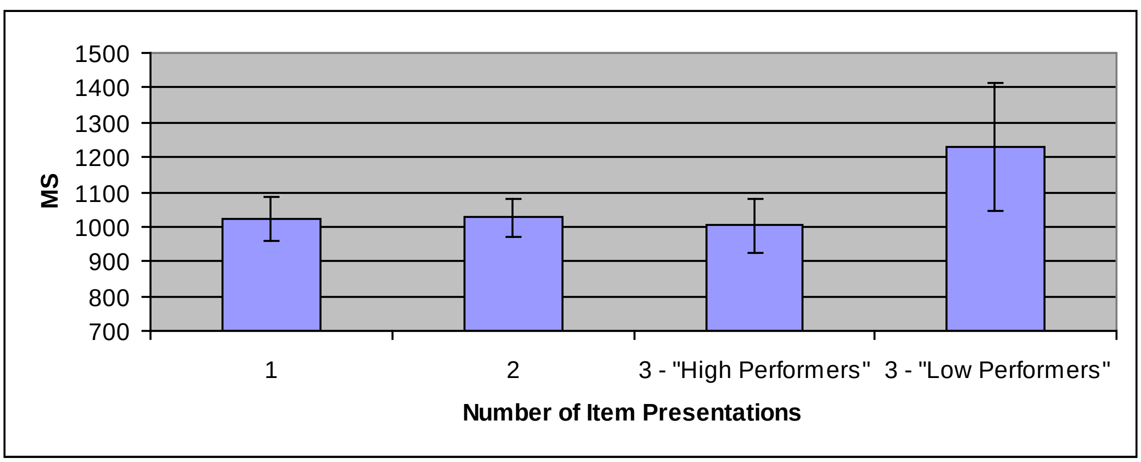


Figure 2.2

Mean RT by Condition Separated at 3 Presentations by "High" and "Low" Performers



Discussion

The results of this experiment indicate that while a BSVP presentation allows the opportunity for perceptual grouping to occur, it does not seem to guarantee it. In fact, the data suggested that there may be groups of “high” and “low” performers and indeed in follow-up analyses the “low” performers did produce reaction times indicative of an item enumeration strategy whereas the “high” performers produced faster reaction times, suggesting use of a familiarity-based strategy. These results are consistent with the notion that linguistic stimuli can be grouped in a somewhat non-traditional way (i.e., into groups of three identical letters rather than into groups that form words). Whether letters are grouped or processed sequentially appears to depend on the individual and therefore may represent a voluntary strategy choice.

Experiment 3

Method

Participants.

Twenty University of Windsor undergraduate psychology students (18 female, mean age = 20.75 years, age range = 18-34) participated in this experiment and were awarded with partial course credit. This number exceeds the 14 participants suggested by the large effect size (at least Cohen’s d = .70) found with RB and a power analysis using an alpha level of .05 and G*Power software. Participants were required to have normal or corrected-to-normal vision as well as English as a first language.

Stimulus Materials and Design.

Stimulus materials consisted of four-letter words with an orthographic neighborhood of between three and four (Durda & Buchanan, 2006). Words with low orthographic neighborhoods have been shown to be better recalled in RB tasks and should reduce the likelihood of orthographic similarity between unrepeated items (Coltheart & Langdon, 2003; Morris & Still, 2008). Words containing the letter M or W were excluded so the same stimuli could be used in the BSVP version of this in Experiment 4, where the width of these letters would have prevented the item from properly fitting within two degrees of visual angle from the display's center. The word list is provided in Appendix A. In all other respects this task was the same as Experiment 1, with trials consisting of either one, two, or three presentations of the target word.

Apparatus and Procedure.

Apparatus and procedure were the same as in Experiment 1, with the exception that words instead of letters were used as items. The modal exposure duration for this experiment was 100ms and the range was 86-142ms.

Results

Separate one-way, repeated measures analysis of variances (ANOVAs) were conducted on the accuracy (mean percent correct) and reaction time data at each level of the IV (number of presentations of the critical item). Analyses were performed both by participant and by item, but they revealed a similar pattern of results. Accordingly, only the participant data will be reported.

The ANOVA for accuracy revealed a large main effect of number of presentations, $F(1.50, 28.56) = 27.23$, $p < .001$, $\eta^2 = .59$.[2] Bonferroni-corrected comparisons were made and the expected RB effect was found for the repeated (M = 67%, SD = 24%, CI = 56-78%) as compared to the unrepeated condition (M = 88%, SD =

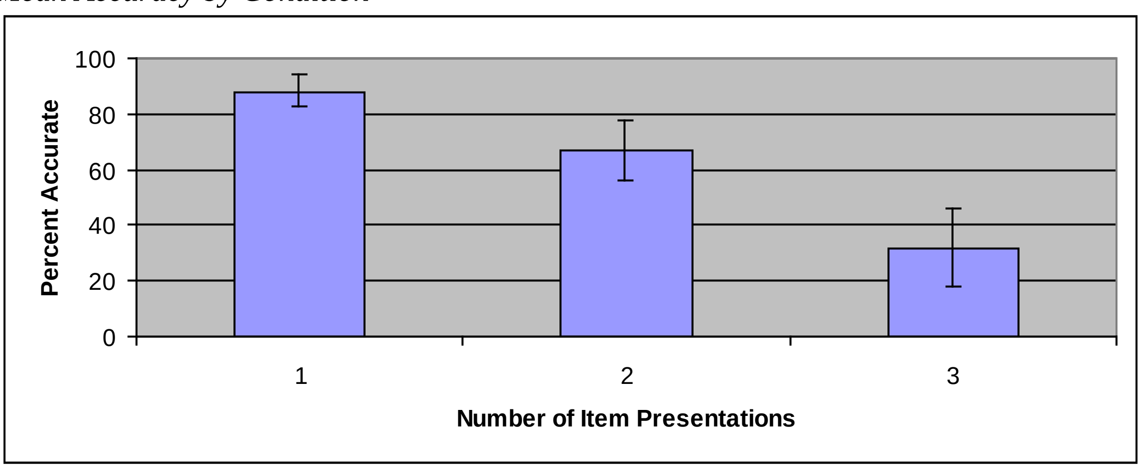
[2]Greenhouse-Geisser correction applied for violation of assumption of homogeneity of variances.

12%, CI = 83-94%, $p = .002$). Decreased accuracy was also found at three presentations of the critical item (M = 32%, SD = 30%, CI = 18-46%, $p < .001$) with perusal of the data indicating that this, too, was a result of underestimation of items, indicating a RB effect. Accuracy at three presentations was also decreased when compared to accuracy at two presentations ($p = .003$). Descriptive statistics are presented in Figure 3.1.

Sixteen individual cases were removed from the RT analysis, a total of 2%. The ANOVA found a large effect of number of presentations, $F(1.34, 16.11) = 11.31$, $p = .002$, $\eta^2 = .49$.[3] Bonferroni-corrected comparisons were performed and suggested a possible item enumeration strategy as three presentations of the critical item (M = 1202ms, SD = 231ms, CI = 1068-1335ms) elicited a longer reaction time than one (M = 946ms, SD = 183ms, CI = 841-1052ms, $p = .002$). Mean differences between one and two presentations ($p = .08$) and two and three presentations ($p = .095$) were in the direction anticipated by an item enumeration strategy, but only approached significance. Descriptive statistics are presented in Figure 3.2.

Figure 3.1

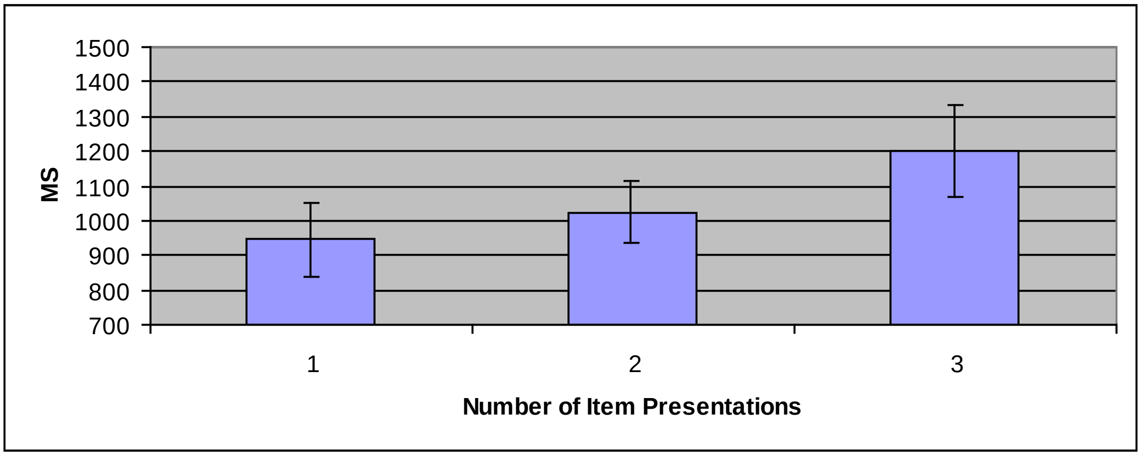
Mean Accuracy by Condition



[3]Greenhouse-Geisser correction applied for violation of assumption of homogeneity of variances.

Figure 3.2

Mean RT by Condition



Discussion

The results of Experiment 3 mirror those of Experiment 1. Repetition blindness was observed at two and three presentations of a word and the pattern of RTs across conditions was indicative of an item enumeration strategy. Like Experiment 3, this suggests that items presented sequentially are subsequently processed sequentially and subject to RB.

Experiment 4

Method

Participants.

Participants were 20 University of Windsor undergraduate psychology students (18 female, mean age = 19.75, age range = 18-34) subject to the same requirements and receiving the same credit as indicated in previous experiments.

Stimulus Materials and Design.

Stimulus materials and design were the same as Experiment 3 with the exception that items were presented using a BSVP format. The display as a whole was centrally located on the computer monitor with items presented in the four quadrants of a square. Each word was presented within two degrees of visual angle from the center of the square.

Apparatus and Procedure.

The apparatus and procedure was the same as used in previous experiments, with the exception that the modal exposure duration for the items was 114ms with a range of 72-184ms.

Results

Separate one-way, repeated measures ANOVAs were conducted on the accuracy (mean percent correct) and RT data at each level of the IV (number of presentations of the critical item). Analyses were performed both by participant and by item, but they revealed a similar pattern of results. Accordingly, only the participant data will be reported.

One participant in this experiment performed below the accuracy cut-off of 35% and thus their data was not included in the following analyses. The ANOVA for accuracy found a large main effect of number of presentations, $F(2, 36) = 27.20$, $p < .001$, $\eta^2 = .60$. Bonferroni-corrected comparisons were made and the expected RB effect was found at two presentations (M = 45%, SD = 25%, CI = 33-57%) as compared to the single presentation condition (M = 74%, SD = 18%, CI = 66-83%, $p < .001$). Decreased accuracy (as compared to one presentation) was also found at three presentations of the critical item (M = 41%, SD = 26%, CI = 28-54%, *p* < .001) with perusal of the data indicating that this, too, was a result of underestimation of items, suggesting an RB effect. No differences were observed between two and three presentations. Descriptive statistics are presented in Figure 4.1

Nineteen individual cases were removed from the RT analysis, a total of 3% of data. The ANOVA for mean accurate RT did not find any effect of number of presentations, but the analysis was underpowered $F(1.45, 26.09) = 1.96$ $p = .155$, $\eta^2 = .10$, observed power = .38.[4] Similar to Experiment 2, it was suspected that a mix of strategies was complicating the picture. A split of high performers (M = 69%, n = 7) and low performers (M = 25%, n = 12) was made and an independent samples t-test was performed on their mean accurate RTs.

It was hypothesized that the low performers were likely using an item enumeration strategy and would thus have longer RTs. The high performers , on the other hand, were suspected to be achieving their success by using a familiarity based strategy and would likely display shorter RTs. The two groups did differ, $t(17) = 2.504$, $p = .023$, suggesting the high performers' (M = 950ms, SD = 158ms, CI = 804-1097ms) did have reliably shorter RTs than the low performers (M = 1137ms, SD = 157ms, CI = 1038-1237ms) and were likely using different strategies. See Figure 4.2 for a graphic display.

[4]Greenhouse-Geisser correction applied for violation of assumption of homogeneity of variances.

Figure 4.1

Mean Accuracy by Condition

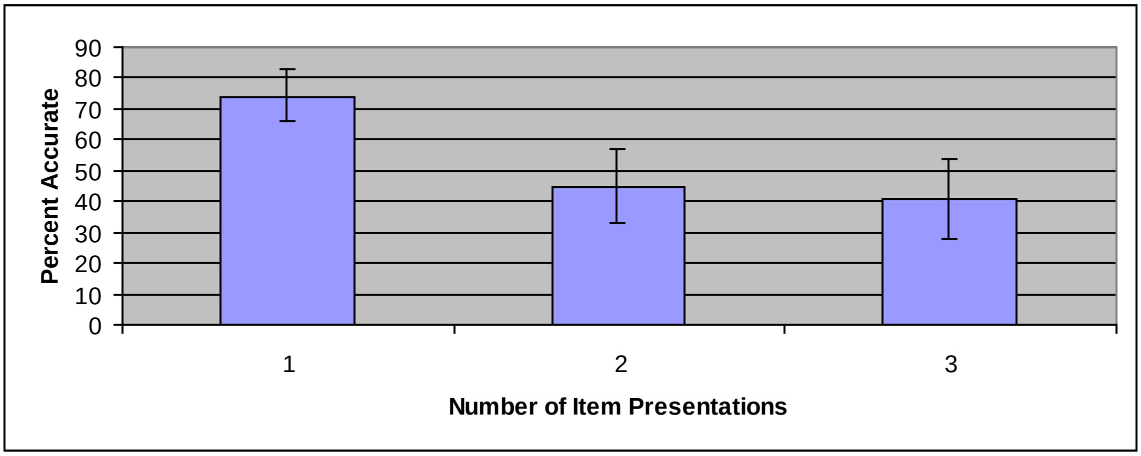
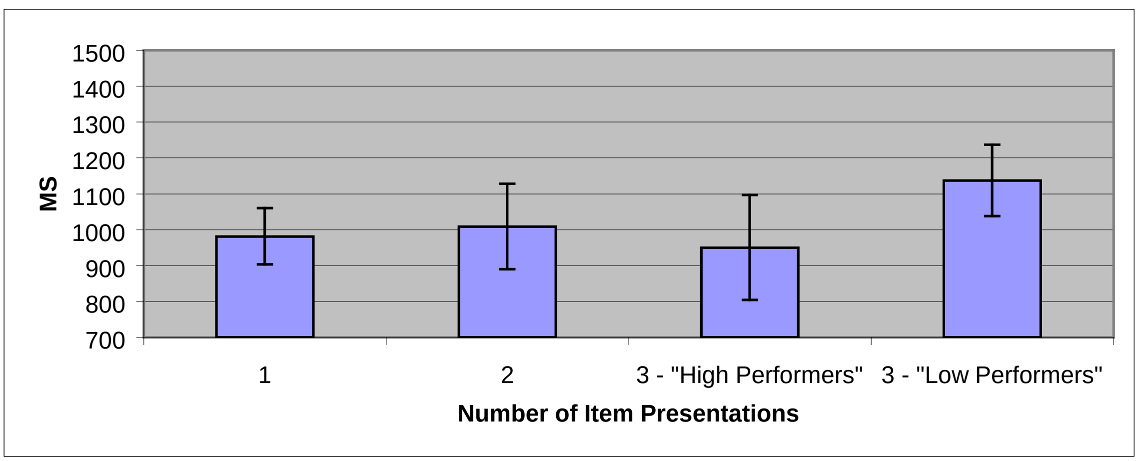


Figure 4.2

Mean RT by Condition Separated at 3 Presentations by "High" and "Low" Performers



Discussion

Akin to the previous experiments, the data overall indicate RB at two and three presentations of a word. At first glance, the pattern of RTs suggests a flat familiarity-based strategy was used. However, when a similar procedure of comparing "high" and "low" performers was used, RT patterns also diverged in a predictable manner. Similar to what was seen in Experiment 2, the participants exhibiting greater accuracy ("high" performers) also had faster RTs when compared to the participants exhibiting poorer accuracy scores. This suggests that “high” performers used a familiarity-based strategy, while “low” performers used an item enumeration strategy.

General Discussion

Taken together, these experiments suggest that when linguistic items are presented sequentially, they are processed sequentially and judgments of frequency are made using an item enumeration strategy. This strategy is manifested in RTs of increasing duration as the number of items increases. This kind of processing leaves viewers vulnerable to RB when items are repeated irrespective of the number of repeated items. In other words, there appears to be no benefit of item grouping under these conditions.

This holds true regardless of the complexity of the linguistic stimuli, as similar patterns emerge for both single letters (Experiment 1) and words (Experiment 3). It is consistent with Mozer’s (1989) research, which found repetition blindness when letters were presented simultaneously, but it does not strongly contest Goldfarb and Treisman’s (2011) research. This is because Goldfarb and Treisman (2011) suggested that grouping would be less salient in sequential displays, which would likely preclude a viewer from benefiting from a grouped presentation.

The experiments that used simultaneous displays of the stimuli (Experiments 2 and 4) showed a different pattern of results. Overall, they appeared to support Mozer’s (1989) claim that presentation of groups of identical stimuli result in underestimation of their total amount. This makes sense, given a reader’s propensity to group letters into words and words into phrases rather than to group linguistic stimuli by identity. This is supported by Abram et al's (1996) finding that RB can be prevented by presenting phrases in syntactically appropriate groups.

However, not all participants exhibited a clear-cut RB effect at three presentations of a letter or word. Instead, there appeared to be two groups of participants within these experiments – a group that had fairly good accuracy at three presentations and a group that had fairly poor accuracy at three presentations. These differences in accuracy scores were mirrored by differences in RTs, whereby those with longer RTs tended to have lower accuracy scores. In other words, those who used an item enumeration strategy exhibited RB, while those who used a familiarity-based strategy seemed to benefit from the grouped presentation.

The disparity of results in the simultaneous experiments lends support to Goldfarb and Treisman's (2011) research in the sense that some participants did appear to group items. Those that grouped items also had a flatter pattern of RTs, which falls in line with Goldfarb and Treisman's (2011) contention that grouping is possible when the group of three items is instead perceived as a single item with several features. This "single item" would not necessarily be expected to produce a longer RT than that of any other multi-featured "single item" display. This explanation is also consistent with Kanwisher's (1987) token individuation hypothesis, as a single item would necessarily escape RB. When items are not grouped, but rather enumerated individually, RB as well as a pattern of increasing RTs would be expected.

The existence of the "high" and "low" performers also points to the main limitation of the study. Namely, it was assumed that the mere creation of groups (putting three items together in a display) would guarantee that participants would perceptually group the linguistic items if this strategy was possible. However, physically grouping items does not appear to be sufficient, by itself, to produce this strategy in participants.

This suggests that other factors that may contribute to the adoption of a specific strategy. Perhaps directly instructing participants to enumerate or gather a general impression of the stimuli may have made a difference, rather than leaving the participants to form their own strategy. Another possibility would be to have replicated Goldfarb and Treisman’s (2011) use of colored stimuli to encourage grouping. For example, the group of three items could have been presented in a distinct color, which may have encouraged their being grouped perceptually by participants.

Discovering that participants likely used different strategies to perform the BSVP tasks calls into question whether the more straightforward results obtained with the RSVP tasks represent a complete constraining of an individual’s strategy choice or whether it merely managed to sway enough participants towards an item enumeration strategy to produce overall results consistent with that strategy. This may be one explanation for not seeing such sharp increases in RT across conditions as described by Brown et al (2000), but rather a shallower, yet still present, increase. Future research is needed to elucidate these points.

Repetition blindness is a robust effect, representing a failure at the intersection of language, perception, and memory encoding. Investigation of RB therefore is able to inform all three of these cognitive domains. Specifically, it provides insight into how language is perceived, accessed, and stored in the brain. Investigation of conditions and manipulations that can successfully circumvent such an error in processing represent the building blocks to uncovering how more naturalistic errors in processing (e.g., neuropsychological impairment) can be remediated. This study in particular illustrates that use of perceptual grouping and a familiarity-based strategy has the potential to overcome weak, unstable, or largely unsuccessful encoding of episodic information. Further, it suggests that despite the type (linguistic) and the complexity (single letters or words) of stimuli, perceptual grouping can be used to preclude such errors.

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Appendix A

Table 2

Stimuli Used in Experiments 3 and 4

		Words			
ABLE	DEFY	GOAL	LOAF	REEF	THUS
ACHE	DENY	GOLF	NAVY	REIN	TIER
ACID	DIAL	GORY	NEON	RISK	TOGA
ACRE	DRIP	GREY	OAFS	ROSY	TROD
ACTS	DROP	GULF	OAKS	RUIN	TROT
AEON	DRUG	GULP	OILS	SALT	TUBA
AIRY	DUAL	HALO	OILY	SELF	TUBE
ALAS	DUCT	HOBO	ONTO	SHUN	TUNA
ALOE	DULY	HURT	OPEN	SIGH	TURF
ASKS	ERAS	HYPE	OURS	SIZE	TYKE
AUNT	EVEN	ICES	OVER	SNIP	UNTO
AVID	EXES	INKS	OXEN	SNUB	USER
AXON	FISH	INTO	PITY	SOAK	VARY
BIRD	FOLK	IRIS	PLAN	SODA	VEIN
BLAB	FREE	IRKS	PLEA	SOFA	VERB
BLIP	FROG	JOIN	PLUG	SOUL	VIAL
BLOC	FUEL	JURY	POET	STUB	YAKS
BODY	FUND	KEYS	PREP	STUD	YELP
BRED	FURY	KNOB	PREY	STUN	YULE
CHEF	FUSE	KNOT	PULP	SUCH	
CHUG	GALA	LADY	PUTT	SURF	
CLUE	GIRL	LAZY	QUAD	TECH	
COAX	GLUT	LION	QUIZ	TEXT	
DEBT	GNAT	LISP	RACY	THIS	

Note. Descriptive Note. Compiled from Wordmine2, Durda, K. & Buchanan, L. (2006).

WordMine2 [Online] Available: http://web2.uwindsor.ca/wordmine

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